UNCERTAINTY AND SENSITIVITY ANALYSES FOR THE RECERTIFICATION OF THE WASTE ISOLATION PILOT PLANT

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The Waste Isolation Pilot Plant (WIPP) is the only operational deep geologic repository in the world for transuranic nuclear waste. WIPP opened for disposal activities in March 1999, after acceptance by the U.S. Environmental Protection Agency (EPA) of the U.S. Department of Energy's (DOE) Compliance Certification Application (DOE, 1996). Fundamental to the compliance application was a probabilistic analysis of repository performance, termed a performance assessment. WIPP is required to apply for re-certification within five years of first receipt of waste. For the Compliance Recertification Application that is due to the EPA by March 2004, Sandia National Laboratories is conducting a new performance assessment that will consider new and changed information since the first certification.

Performance assessment for WIPP applies sampling-based uncertainty and sensitivity analyses to demonstrate compliance with the regulations governing the repository. As required by the,EPA which regulates the WIPP, performance assessment includes both stochastic (aleatory) uncertainty about future events at the repository, such as drilling for natural resources and mining for potash, and subjective (epistemic) uncertainty about the models and parameters used in the calculations. (EPA 1994, EPA 1996). The performance assessment thus computes a distribution of cumulative complementary distribution functions (CCDFs) for radionuclide releases from the repository (Figure 1), in which stochastic uncertainty determines the shape of each CCDF, and subjective uncertainty determines the distribution of CCDFs. (Helton et al 2000)

The distribution of CCDFs is formally computed by a double integral over the probability spaces for stochastic uncertainty *ST* and subjective uncertainty *SU*:

$$\Pr(p \geq P|R) = \int_{SU} \delta_P \left[\int_{ST} \delta_R \left(f(x_{st}, x_{su}) \right) d(x_{st}|x_{su}) d\mu_{st} \right] d(x_{su}) d\mu_{su} \qquad (1)$$

where $\delta_Y(x) = 1$ if $x \geq Y$, and $\delta_Y(x) = 0$ if $x < Y$. The integral over subjective uncertainty is evaluated using Latin Hypercube Sampling (LHS) (McKay et al 1979). The integral over stochastic uncertainty is evaluated by Monte Carlo sampling, as implemented in the code CCDFGF (WIPP PA 2003). The real-valued function *f* in Equation (1) maps elements in the probability spaces (stochastic and subjective) to releases, and is evaluated for a small set of representative elements in the probability spaces; releases for other elements are constructed by interpolation. The evaluation of *f* comprises a series of deterministic models for important physical processes and events, including: closure of excavated regions over time; two-phase flow of brine and gas in and around the repository; radionuclide decay and mobilization in brine;

radionuclide transport; and direct releases resulting from a drilling intrusion into the excavated area. (Helton et al 1998)

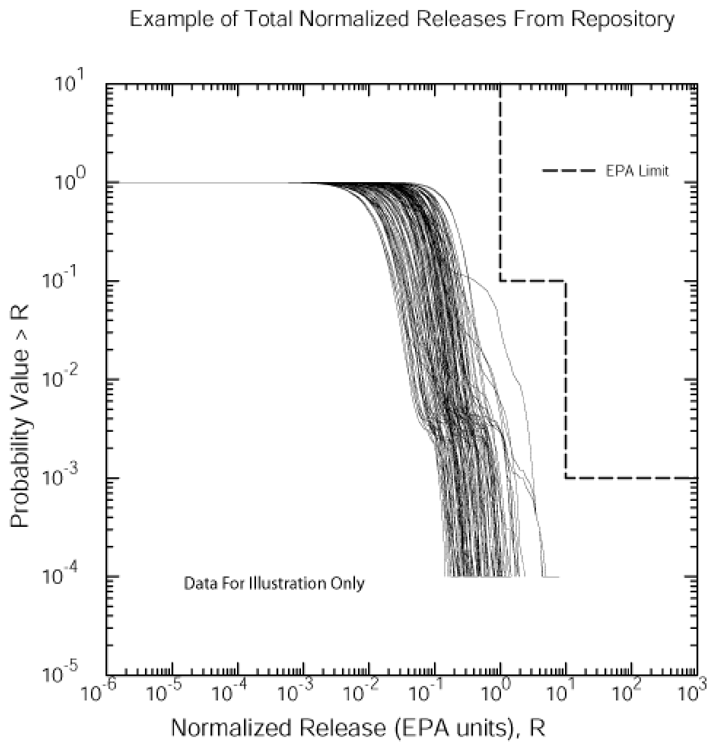

Figure 1. Example of Distribution of CCDFs for WIPP Performance Assessment.

Most of these numerical models compute the solution of systems of partial differential equations, derived from physical principles for the processes involved, and computed for materials representing the waste and the surrounding geologic media.

Computation of the distribution of CCDFs by sampling techniques comprises the uncertainty analysis for the performance assessment, and illustrates the possible performance of the repository for the regulatory period. Sensitivity analysis determines which subjectively uncertain models or parameters are significant to the uncertainty in the results. Uncertainty and sensitivity analyses for the performance assessment for the certification of WIPP are reported by Helton et al (1998) and Helton and Marietta (2000).

The performance assessment for certification assumed that waste would be emplaced randomly throughout the repository, and thus represented waste as a homogeneous material. This assumption reflects subjective uncertainty about the waste inventory and stochastic uncertainty about the arrival of waste shipments. The level of detail in the models of physical processes (i.e., two-phase flow) reflects this assumption. Since certification, DOE is seeking approval to accept supercompacted waste, which has mechanical properties and chemical composition that may be significantly different from the modeled homogeneous waste material. (DOE 2002) In addition, shipments to the WIPP have been received in groups of waste streams from waste generator sites and have resulted in correlations in the spatial location of containers of similar waste. The request to accept supercompacted waste and the observed waste emplacement to date have led to questions from EPA and other stakeholders about whether the actual emplacement patterns are consistent with waste representation assumed in the performance assessment for certification. (EPA 2003, EEG 2003) The questions have led to an analysis that attempts determine the uncertainty in performance assessment that arises from heterogeneity in the waste material, and a sensitivity analysis to determine which heterogeneous properties are significant to performance assessment results.

Conceptually, performance assessment could treat the spatial arrangement of waste as a subjectively uncertain element, treating the structural and chemical properties of waste as spatial variables. Such a treatment would be prohibitively expensive to implement, due to the model refinement that would be required and the additional cost of computing closure of excavated regions for many different configurations of waste. Accordingly, an uncertainty and sensitivity analysis was designed to determine if either waste structural properties or the spatial distribution of gas generating reactants were significant to performance assessment results. The uncertainty analysis followed the computational strategy for the performance assessment, excavation closures were computed for a small number of possible waste container configurations, and indices to these configurations were included in the LHS. A second LHS parameter determined the distribution of reactants within the waste-filled regions.

Sensitivity analysis is conducted using scatterplots and regression techniques. These simple tools are effective at determining both the effect of the additional sampled variables on performance assessment results, and whether waste heterogeneity should be represented in WIPP performance assessment models. This paper will outline the uncertainty and sensitivity analyses conducted to examine the effects of waste heterogeneity on the performance assessment for the recertification of the WIPP.

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